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Evaluating Potential Biodegradable Twine for Use in the Blue Swimming Crab Collapsible Pots

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ABSTRACT: This study addresses the global issue of lost fishing gear, specifically traps and pots, which rank second regarding gear lost in marine environments. These traps often contain synthetic fibers that decompose slowly, producing long-lasting ghost fishing. To mitigate this problem, the study explores using biodegradable materials in trap construction. The research focuses on assessing biodegradable materials' physical and mechanical properties and how immersion affects them. Field surveys and sample immersion were conducted at Kejawanan Fishing Port Cirebon, with subsequent testing at IPB University. The study compared three natural materials: cotton, agel, and hemp twines. The cotton twine stood out with its soft texture compared to the rougher agel and hemp twines. Regarding elongation, cotton 20.76% outperformed agel 13.70% and hemp 4.42%. Sequential breaking strength tests revealed cotton's superior strength at 9.84 kgf over agel at 3.61 kgf and hemp at 2.72 kgf, even after immersion. These findings indicate that cotton twine is a viable biodegradable alternative to synthetic twines in blue swimming crab pot fishing. By adopting such materials, fishermen can reduce the environmental impact of lost gear and contribute to more sustainable fishing practices.

KEYWORDS: Biodegradable material, Ghost fishing, Natural Fiber, Twine Characteristic, Pot.

I. INTRODUCTION

Fishing gear can be categorized into two distinct varieties based on the basic material employed, particularly nets, which can be fabricated from natural or synthetic fibers. Synthetic fibers, such as polyamide, polyethylene, fiberglass, and monofilament, are fibers produced by humans using chemical synthesis methods. Natural fibers are derived from plants, animals, and geological processes without experiencing any chemical processes or transformations [1] – [2]. The choice of fiber materials is typically determined by several factors, including strength, durability, service life, stiffness level, structure, fish response to the material, and the construction of the fishing gear employed [3]. Certain fishermen continue to utilize natural fiber materials, particularly in collapsible pot fisheries, such as those constructed from bamboo [4]. In certain instances, fishermen have employed synthetic materials, specifically polyethylene, as a binding twine and iron as a frame to construct the collapsible pot's body. This practice has been observed in the case of the crab collapsible pot [5].

Using collapsible pots in fishing is prevalent among fishers, as indicated by its widespread usage. One notable advantage of employing collapsible pot fisheries is the convenience of operation, as highlighted by Herisdiana [6]. Furthermore, producing collapsible pots is a very affordable expense [7]. Collapsible pot captures many species, including reef fish, demersal fish, and crustaceans such as crabs. Nevertheless, there persist issues within collapsible pot fisheries, specifically with the collapsible pot's status as a fishing gear that carries the highest probability of loss, second only to gill nets. According to a study conducted by Matsuoka et al. [8], it has been established that collapsible pots are commonly lost at sea due to the entanglement of the buoy twine with either the floating net cage or submerged rocks. Collapsible pots have been identified as a significant source of lost fishing gear in marine environments, as indicated by various scholarly sources [9 - 11]. According to the World Wildlife Fund [11], the worldwide proportion of lost fishing gear is approximately 5.7% for fishing nets, 8.6% for traps, and 29% for fishing lines.

The possibility for ghost fishing is significantly heightened when collapsible pots are lost at sea as they transform into marine debris. Ghost fishing refers to the phenomenon wherein fishing equipment that has been inadvertently lost or deliberately abandoned in the marine environment remains active, entangling and capturing fish and other marine organisms until it becomes ineffective due to deterioration or decomposition [12 - 14]. The phenomenon known as ghost fishing poses a significant risk to aquatic mammals. This threat not only results in harm and mortality, but it also ensnares marine species that are legally protected, including sea turtles [15 - 19]. The issue of ghost fishing in trawl fisheries warrants attention due to the robust construction and lasting materials employed in trawls, which result in a comparatively prolonged ghost fishing effect compared to nets [20 - 21]. In addition, it should be noted that a constituent element within the collapsible pot is a synthetic fiber, namely a polymer derived from a plastic base material. Macfadyen et al. [22] research indicates that this particular synthetic fiber requires approximately 600 years to complete decomposition.

One potential strategy to mitigate the effects of ghost fishing involves using biodegradable materials with a higher decomposition rate than synthetic materials, namely in a designated section of the collapsible pot. When the collapsible pot is misplaced for a prolonged period, the biodegradable material will undergo decomposition, resulting in a diminished capacity to capture the collapsible pot. Consequently, the likelihood of fish becoming ensnared and perishing in ghost fishing before being exploited by fishermen is reduced. Researching the physical and mechanical properties of various natural materials is imperative to explore viable natural material options for collapsible pot fishing gear. These materials, including agel twine, cotton, and hemp, are potential alternatives for constructing collapsible pots. The objectives are to identify the most suitable biodegradable material for collapsible pot fishermen.

This study contributes to mitigating the environmental consequences of ghost fishing in the collapsible pot fishery. The objective is to examine the physical and mechanical properties of agel, cotton, and hemp twines utilized in constructing collapsible pots to minimize the likelihood of ghost fishing. Additionally, the study aims to compare the impact of soaking on the breaking strength and elongation of agel, cotton, and hemp twines when employed in the collapsible pot fishery. The objective of this study is to offer suggestions for biodegradable materials that fishermen can use as a substitute for conventional materials in the construction of collapsible pots, aiming to mitigate the adverse effects of ghost fishing. Therefore, the collapsible pot fishery is ultimately enhanced regarding its environmental sustainability.

II. MATERIALS AND METHODS

A. Time and Place

The study was carried out from June to October 2022. Researchers conducted field surveys and sample soaking activities at the Kejawanan Fishing Port in Cirebon. In addition, the mechanical properties of the test specimen were evaluated at the Wood Building Engineering and Design Laboratory, located within the Department of Forest Products at the Faculty of Forestry, IPB University. The physical parameters of the test material were assessed in the Integrated Laboratory of the Department of Fisheries Resource Utilization, Faculty of Fisheries and Marine Science, IPB University.

B. Tools and Materials

The research utilizes several pieces of equipment, including a ruler for measuring the length of the twine, a vernier for measuring the diameter of the material, a Universal Testing Machine (UTM) for assessing the twine's breaking strength and stretching capabilities, a modified collapsible pot without a mouth for accommodating plastic containers used for sample immersion, and plastic containers for holding the materials. The materials employed in this investigation include hemp twine with a diameter of 1 mm, agel with a diameter of 1.5 mm, cotton twine with a diameter of 1.5 mm, and seawater utilized as the soaking medium. The materials utilized exhibit dimensions ranging from 1 to 1.5 millimeters in size.

C. Method of collecting data

Data collection in the field involved using direct observation techniques to ascertain the oceanographic factors associated with twine immersion. Data on the physical characteristics of the twine include color, stiffness, tactile impression, and direction of twine twisting. In contrast, data on the twine's mechanical characteristics include breaking strength and extensibility of agel, cotton, and hemp twines. The data required for the second objective compares the effect of twine soaking, namely the breaking strength and elongation of agel, cotton, and hemp twines after soaking in seawater seawater and over the research period the water temperature between 27°C – 32.9°C, salinity varied between 12 – 19.1 ppt, and acidity 7.4 – 8.2. Based on this research, recommendations for applying biodegradable twines can be obtained to reduce the impact of ghost fishing in the collapsible pot fishery.

D. Data analysis

Descriptive methods were employed to study the physical and mechanical features of agel, cotton, and hemp twines. This study aimed to identify the factors influencing the physical attributes of twines, specifically color, texture, rigidity, and twisting direction. In addition, it is anticipated that a comprehensive account will be provided concerning each twine's extensibility and breaking strength following the soaking process.

The data analysis for the second aim employed a one-factor, completely randomized design (CRD) study to optimize decision-making about implementing a novel technology, process, or policy. Assuming that the outcomes of the analysis of variance (ANOVA) lead to the rejection of the null hypothesis (H_0), it can be inferred that a significant disparity exists between the twines employed. In this scenario, a post hoc analysis is conducted using the Tukey test to compare the treatment means collectively after performing a variance test [23]. The objective is to determine which type of twine exhibits a statistically significant superiority. This study is a comparative analysis of the breaking strength and elongation characteristics of different types of twines.

The optimal recommendation for placing biodegradable twines utilizing the Corel Draw application can be determined by examining the first and second objectives. The forthcoming research will involve a descriptive examination of the data, which consists of visual representations depicting various twine installation designs on collapsible pots.

III. RESULTS AND DISCUSSION

Identifying Physical And Mechanical Characters Of Biodegradable Twine

A. *Character Physical Biodegradable Twine*

Physical characteristics refer to the inherent properties of a twine that may be directly viewed without additional testing. Understanding the physical attributes of a material intended for utilization as a fishing implement proves advantageous. The physical attributes of natural twine materials, such as agel, cotton, and hemp, exhibit distinct variations. The variations in these attributes encompass hue, rigidity, surface quality, rotational orientation, and cord circumference, as illustrated in Figure 1 and Table 1.

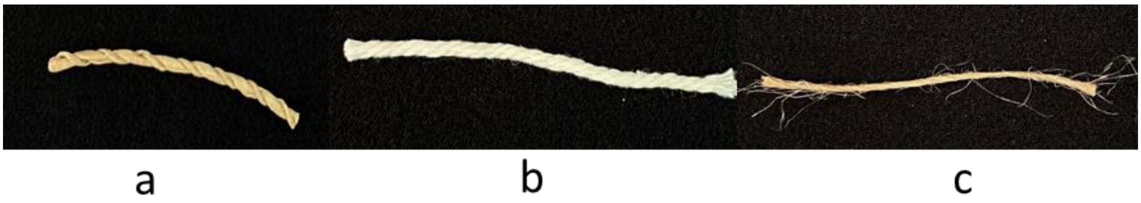

Figure 1. Natural materials (a. agel, b. cotton, c. hemp)

Table 1. Characteristics natural physical materials

Twine	Twine Type	Characteristics Twine Physical				
		Color	Stiffness	Texture	Direction twist	Diameter
1	Agel	tanned	Rigid	Rough	Z	1.5
2	Cotton	White	Rather rigid	Soft and smooth	S	1.5
3	Hemp	Beige	Rather rigid	Rough	Z	1

In general, the outcomes derived from physical observations conducted on twines made of agel, cotton, and hemp exhibit discernible disparities, particularly in coloration, texture, and twisting orientation. Syahailatua [24] posits that the durability and flexibility of a material are influenced by its physical attributes, such as the number of twists, fiber type, texture, and yarn diameter. According to the findings of the study, it was observed that agel twine has a mostly brown hue in comparison to other varieties of twine. The brownish hue of agel twine results from the drying process of light green or yellowish palm leaves, which are subsequently twisted into a twine [3]. On the contrary, hemp twine exhibits an initial white hue.

Nevertheless, the extended manufacturing procedure and the potential occurrence of tannin contamination during the production process impact the alteration of hue to beige in hemp twine [25]. In contrast to agel and hemp twines, cotton twines possess a pristine white hue that exhibits a degree of transparency, rendering them unnoticeable while submerged in water. Consequently, cotton twines are highly ideal for use as materials in fishing gear. The chromatic properties of the fishing equipment material have a discernible impact on the diversity of fish species captured. Hence, it is advisable to modify the color of the fishing gear material to the prevailing water conditions, avoiding high contrast that contrasts with the water's color and the color of its bottom. The study's findings indicate that agel and hemp twine exhibit similar physical texture and twisting direction characteristics. This analysis examines the contrasting physical attributes of cotton twines, characterized by their softness, smoothness, and increased rigidity.

B. *Character Biodegradable Twine Mechanic*

The mechanical properties of agel, cotton, and hemp twines are directly associated with their breaking strength and extensibility. The relationship between the twine's physical features and its breaking strength and extensibility (mechanical characteristics) is a significant factor to consider. Various types of twine have distinct breaking strengths. Specifically, agel twine demonstrates a breaking strength of 3.61 kgf, cotton twine exhibits a breaking strength of 9.84 kgf, and hemp twine possesses a breaking value of 2.72 kgf. The variation also arises in the extensibility or length increase of each twine. The elasticity of the agel twine is measured to be 47.93 m, while the cotton twine exhibits a stretchability of 72.65 m, and the hemp twine has a stretchability of 15.47 m. The cotton twine exhibits the maximum breaking strength and extensibility, measuring 9.84 kgf and 72.65m, respectively. The hemp twine variant exhibits the lowest breaking strength and extensibility, measuring 2.72 kgf and 15.47 m, respectively. The test results of the mechanical characteristics of the three twines that were subjected to testing can be shown in Figure 3.

The extent of twine elongation is contingent upon the spinning density of individual twines [1]. The cotton-type twine exhibits the highest breaking strength and elongation, measuring 9.84 kgf and 72.65m, respectively. When comparing different types of twines, it is observed that the hemp twine has the lowest breaking strength and elongation, measuring 2.72 kgf and 15.47m, respectively. According to Nofrizal et al. [26], the elongation of a twine is strongly correlated with the fiber's breaking strength. Specifically, when the elongation value is high, the breaking strength likewise tends to be high.

The breaking strength value of a material is influenced by its stiffness. According to Klust [27], a positive correlation exists between a material's stiffness and its susceptibility to breaking. The observed phenomenon can be attributed to the mechanical stress induced during the material testing. When the structural integrity of the material is compromised due to excessive tension, the material will undergo fracture. The findings of this study indicate that cotton fabric exhibits a relatively lower degree of stiffness than alternative materials. Hence, the breaking strength and flexibility of the material surpass that of twines and other comparable materials.

As Safitri [28] posited, a high breaking strength number indicates good elongation, while a low elongation value is associated with the same. The observation above highlights a notable distinction between the properties of the subject in question and those of cotton twine. Specifically, the subject exhibits a significantly elevated breaking strength and extensibility value compared to cotton twine. Nevertheless, this solely impacts the efficacy of the fishing equipment material. Klust [27] posits that the extent of elongation is contingent upon individual webbings' spinning hardness and density characteristics. Additional investigation is required to ascertain the efficacy of cotton twines in the context of fishing operations. According to Safitri [28], an ideal elongation is characterized by a high breaking strength value coupled with a low elongation value. The observed characteristics of cotton twine differ from those of other materials due to its high breaking strength and flexibility.

Nevertheless, the performance of the fishing gear material may not be impacted by this. Klust [27] posited that the extent of elongation is contingent upon individual webbings' spinning hardness and density characteristics. Additional investigation is required to ascertain the efficacy of cotton twines in the context of fishing operations.

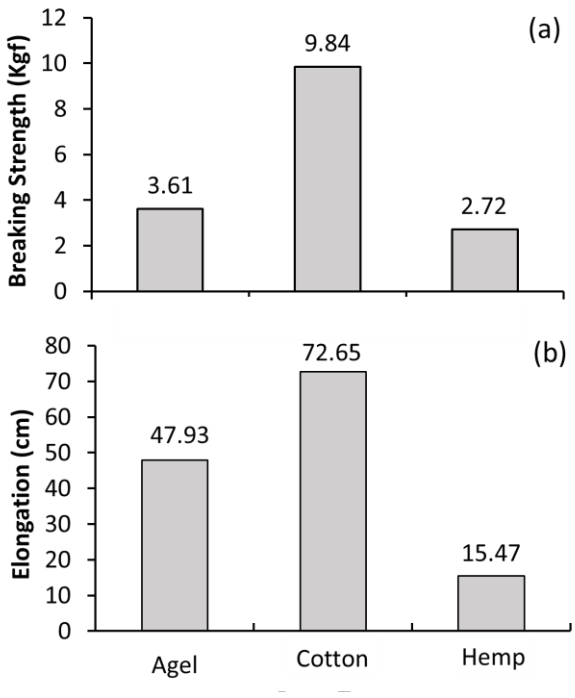

Figure 2. Breaking strength test results (a) and Elongation of twine agel, cotton, and hemp

Comparing the Effect of Immersion on the Breaking Strength and Elongation of the Twine

A. Comparison of the Breaking Strength of the Twine

The breaking strength of each twine that has undergone a 191-day immersion in the sea waters of Kejawanan fishing port Cirebon has diverse values. The cotton twine exhibits the highest average breaking strength value, measuring 2.60 kgf. In comparison, the agel twine demonstrates an average breaking strength value of 0.22 kgf, while the hemp twine possesses the lowest breaking strength value of 0.18 kgf. These measurements were obtained after subjecting the twines to varying soaking times over 103 days. The data indicate that cotton twine has the highest maximum load capacity before rupture compared to alternative twine varieties. Hemp twine exhibits comparatively lower load-bearing strength in comparison to other twine varieties. Figure 4 shows a graphical representation of the breaking strength of twines made from agel, cotton, and hemp.

Following the acquisition of the outcomes from the assessment of the breaking strength for each twine variant, subsequent analysis was conducted employing the analysis of variance technique to determine the type of twine exhibiting the highest breaking strength (Figure 5). In addition, regression tests were performed to determine the soaking duration necessary for the twine's breaking strength and extensibility to be fully depleted. The calculated regression equation for the relationship between soaking time and breaking strength of each type of cotton twine is Y = -0.0343x + 9.0172. The coefficient of determination for the regression model is $R^2 = 0.7785$. This study elucidates the correlation between the breaking strength of cotton twines and the duration of soaking, with the latter exhibiting a significant impact of 77.8%. Based on the derived equation, it is projected that around 262 days following the investigation, the twine's breaking strength will be depleted.

The analysis of variance revealed that the various varieties of twine exhibit a statistically significant effect ($p < 0.05$) on breaking strength. Specifically, the breaking strength of cotton twine was found to be considerably different ($p < 0.05$) from that of agel and hemp twines, which did not exhibit a significant difference between each other.

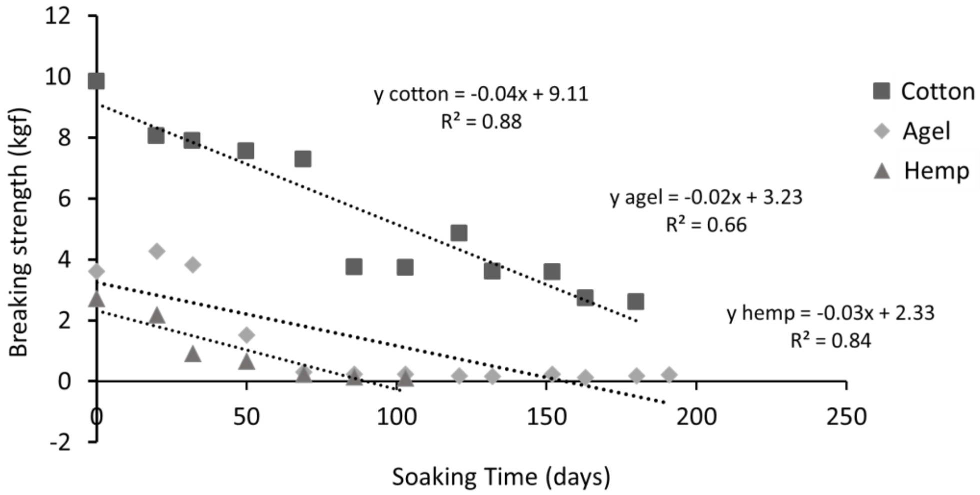

Figure 3. The correlation between the breaking strength of a twine and the duration of soaking of cotton, agel and hemp twines.

B. Twine Elongation Comparison

The test findings for each type of twine, about their extensibility levels after being immersed in seawater for 191 days, exhibit a range of values. The mean extensibility values for cotton, agel, and hemp twine are approximately 10.32%, 6.04%, and 3.72%, respectively. According to the data collected, a fluctuating trend is observed in the percentage of liability for the three varieties of twine (see Figure 3). The duration of immersion in seawater influences the extensibility of different types of twine. The agel twine had the highest percentage of extensibility, while the hemp-type twine demonstrated the lowest. However, considering the duration of immersion, the cotton twine displayed the lowest percentage. This implies that cotton twines exhibit the lowest rate of length increase relative to other twine kinds until the point of degradation.

Following acquiring the pliability comparison results for each twine type, subsequent analysis was conducted utilizing the single component variance analysis approach to determine the type exhibiting superior pliability. The regression analysis revealed a negative relationship between soaking time and the flexibility of each type of cotton twine, as indicated by the equation Y = -0.0301x + 21.124. The coefficient of determination ($R^2 = 0.6025$) suggests that soaking time can explain approximately 60.25% of the flexibility variation. Based on the regression equation, it is estimated that after approximately 701 days following the research, the cotton twine will no longer exhibit pliability. This elucidates the correlation between the extensibility of cotton twines and the duration of soaking, with a significant impact of 60.2%. This phenomenon is more prominently illustrated in Figure 4.

The analysis of variance reveals a statistically significant impact ($p < 0.05$) of various twine types on the mechanical strength test, specifically in terms of twine extensibility. This finding suggests these twines could be a viable alternative material for constructing collapsible pots. Upon conducting additional tests, it has been observed that there is a notable disparity in the extensibility among the three distinct types of twine employed. The statistical analysis reveals that the extensibility of cotton, agel, and hemp twines holds substantial importance, as indicated by their significant values, all of which are less than 0.05.

Among the three types of twine examined, cotton twine has superior mechanical strength due to its notable flexibility and water absorption characteristics. According to Koutu et al. [29], cotton fibers possess elastic and flexible characteristics due to insoluble material and strong intermolecular interactions within the fibers. According to Mulyawan et al. [30], cotton has a significant degree of flexibility, enabling it to effectively accommodate minimal and substantial dimensional alterations.

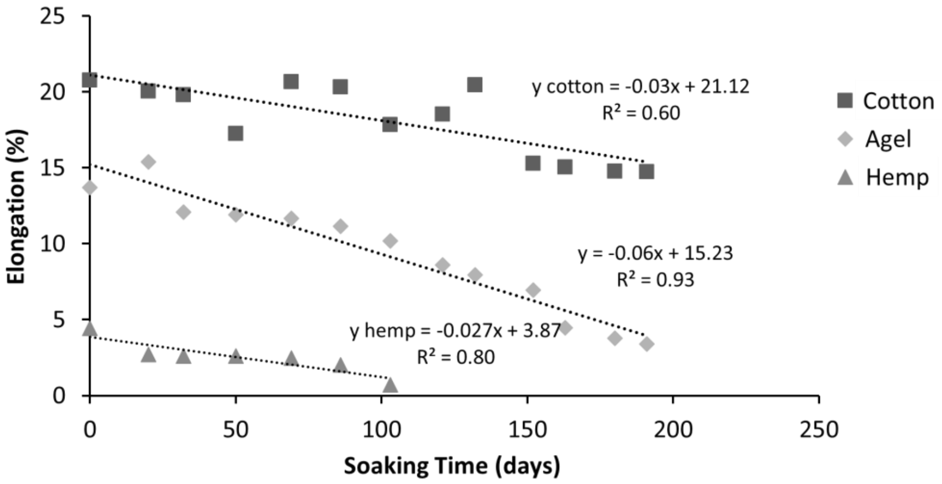

Figure 4. The correlation between the breaking strength of a twine and the duration of soaking for three different materials cotton, agel, and hemp.

The immersion trials conducted on three distinct types of twine exhibit varying stress values. The magnitude of tension generated influences each twine category's shape alteration or deformation rate. The daily tension values of cotton, agel, and hemp twines exhibited fluctuations, with average magnitudes of 0.009, 0.00085, and 0.003, respectively. The experimental results indicate that the cotton twine exhibits the highest average tension value among the three twines examined, while the agel twine demonstrates the lowest. Figure 4 illustrates a negative correlation between the duration of soaking and the magnitude of tension generated by the three twines. According to the information provided, it is indicated that an increase in the length of the submerged twine leads to a drop in the corresponding tension value.

Application of Biodegradable Twine in Blue Swimming Crab Collapsible Pot Fisheries

Based on the breaking strength and elongation test cotton, agel, and hemp twines, the best strength and elongation was the cotton twine. Cotton twines have good elasticity and water absorption properties, and after soaking in seawater for 191 days, cotton twines can withstand the highest maximum load and the lowest level of extensibility. Therefore, cotton twines are suitable to be recommended in collapsible pot fisheries.

The cotton twine has the highest breaking strength compared to other materials tested. In addition, cotton is a natural material that can be decomposed, unlike other plastic materials. Using collapsible pots with cotton material is expected to minimize fishers' operational costs and reduce the impact of ghost fishing when the collapsible pot is lost. Cost efficiency can be done by tying the collapsible pot on one side of the entrance gap. This is so that the parts are quickly

damaged when the collapsible pot is lost so that fish can escape if trapped in the lost collapsible pot. This condition is an effort to minimize the impact of ghost fishing in the collapsible pot fishery.

The use of cotton twine installation on the collapsible pot fishing gear is strategically positioned near the entrance of the collapsible pot. This positioning ensures that if the collapsible pot is lost or drifts in the sea, the cotton twine can undergo degradation. Furthermore, the implementation of twine systems can effectively mitigate the inadvertent entanglement of collapsible pots or uncontrolled capture of fish. Using a cotton twine as a fastening mechanism on a certain section of the collapsible pot enables the possibility of locating it within a timeframe of 275 days or approximately nine months if it becomes misplaced. Figure 5 shows that the string is the initial component to experience failure when the net becomes detached, enabling the fish to elude capture.

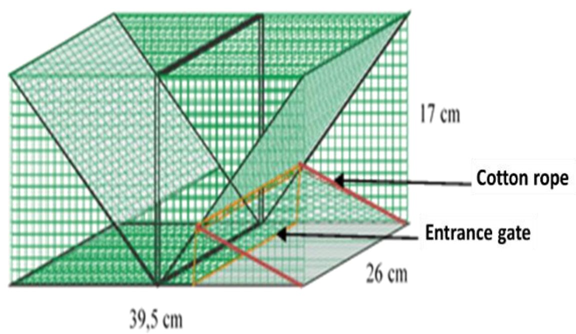

Figure 5. Recommendation placement of biodegradable materials in blue swimming crab pot

CONCLUSIONS

The physical properties of many natural materials exhibit distinct variations. Agel and hemp twines have a brownish hue, a coarse and rigid surface texture, and a twine diameter of around 1.5 mm, characterized by a Z-twisting direction.

The cotton twine has physical attributes such as a white hue, soft and smooth surface texture, and moderate flexibility. Additionally, it possesses a twine diameter measuring 1.5 mm and is twisted in the S direction. The mechanical properties of agel, cotton, and hemp twines were assessed in terms of their respective breaking strengths, which were found to be 3.61 kgf, 9.84 kgf, and 2.72 kgf, respectively. The elongation measurements for agel, cotton, and hemp twines were recorded as 47.93 m, 72.65 m, and 15.47 m, respectively. An inverse correlation is observed between the duration of soaking time and the strength required to break a twine. According to the findings of the investigation, it was observed that cotton twine exhibited the highest breaking strength value in comparison to both agel and hemp twine. Hence, it is advisable to employ this approach as a means of mitigating the adverse effects of ghost fishing in collapsible pot fisheries..

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